A Comparison of Three-Year Survival After Coronary Artery Bypass Graft Surgery and Percutaneous Transluminal Coronary Angioplasty

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Objectives. **The purpose of this study was to compare 3-year risk-adjusted survival in patients undergoing coronary artery bypass graft (CABG) surgery and percutaneous transluminal coronary angioplasty.**

Background. **Coronary artery bypass graft surgery and angioplasty are two common treatments for coronary artery disease. For referral purposes, it is important to know the relative pattern of survival after hospital discharge for these procedures and to identify patient characteristics that are related to survival.**

Methods. **New York's CABG surgery and angioplasty registries were used to identify New York patients undergoing CABG surgery and angioplasty from January 1, 1993 to December 31, 1995. Mortality within 3 years of undergoing the procedure (adjusted for patient severity of illness) and subsequent revascularization within 3 years were captured. Three-year mortality rates were adjusted using proportional hazards methods to account for baseline differences in patients' severity of illness.**

Results. **Patients with one-vessel disease with the one vessel not involving the left anterior descending artery (LAD) or with less than 70% LAD stenosis had a statistically significantly longer adjusted 3-year survival with angioplasty (95.3%) than with CABG surgery (92.4%). Patients with proximal LAD stenosis of at least 70% had a statistically significantly longer adjusted 3-year survival with CABG surgery than with angioplasty regardless of the number of coronary vessels diseased. Also, patients with three-vessel disease had a statistically significantly longer adjusted 3-year survival with CABG surgery regardless of proximal LAD disease. Patients with other one-vessel or two-vessel disease had no treatment-related differences in survival.**

Conclusions. **Treatment-related survival benefit at 3-years in patients with ischemic heart disease is predicted by the anatomic extent and specific site of the disease, as well as by the treatment chosen.**

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Coronary artery bypass graft (CABG) surgery and percutaneous transluminal coronary angioplasty were developed nearly 30 years and 20 years ago, respectively, as alternatives to medical therapy for the treatment of patients with coronary artery disease (1,2).

In recent years, several studies have examined the benefits of these two interventions relative to medical therapy and/or to one another (3–9). For the most part the studies that have compared CABG surgery and angioplasty have not found significant long-term mortality differences. However, with the exception of a single institution study by Jones et al. (7), these studies have grouped patients for analysis only on the basis of the number of diseased coronary arteries. As has been pointed out many years ago by Favaloro (10) and by Ringqvist et al. (11), another important anatomic consideration in the prognosis for patients with ischemic heart disease is the location of the lesion, both with respect to the vessel in which it is located and the location within the vessel. It is likely that a major reason why lesion location was not used in other studies was the limited number of patients in these studies, most of which were randomized clinical trials.

This study uses prospectively defined data from New York State cardiac procedure registries in conjunction with mortality information from the state's Vital Statistics data system to compare 3-year outcomes for CABG surgery and angioplasty for nearly 30,000 patients undergoing each of the interventions. The purpose of studying this large population was to identify preoperative clinical and angiographic variables that predicted differences in survival among CABG surgery and angioplasty patients and, in particular, to control for lesion location when assessing differences.

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Abbreviations and Acronyms

CABG	=	coronary artery bypass graft
CARS	=	Coronary Angioplasty Reporting System
CHF	=	congestive heart failure
CSRS	=	Cardiac Surgery Reporting System
LAD	=	left anterior descending artery

Methods

Study population. Patients in the study consisted of those patients who were New York residents who underwent isolated CABG surgery (CABG surgery with no other major open heart procedures in the same admission) or angioplasty between 1/1/93 and 12/31/95 in New York, who had no previous revascularization, did not have left main disease (defined as stenosis >50%) and did not suffer an acute myocardial infarction during the 24-h period prior to undergoing revascularization.

Two registries in New York State, the Cardiac Surgery Reporting System (CSRS) and the Coronary Angioplasty Reporting System (CARS), are the sources of the patients in the study. These systems include numerous patient risk factors; admission, surgery and discharge dates, and discharge status.

With the exception of some additional lesion-specific information in CARS, the registries contain exactly the same data elements and definitions. Also, the same process was used to train the 31 hospital cardiac surgery departments responsible for coding the CSRS forms and the 32 hospital cardiac catheterization laboratories responsible for coding the CARS forms to capture the relevant information. When data fields are found to be missing, hospitals are contacted and asked to complete the missing information. Also, comprehensive audits of approximately half of the hospitals in each registry are conducted each year, and several hospitals have been asked to recode all or part of their data as a result of the audits.

Since patients are identified using social security numbers, subsequent revascularizations (CABG surgery or angioplasty) for each patient within New York State can be tracked using the two registries. Patient deaths outside of the hospital, or in the hospital for patients whose subsequent admission is not for the purpose of undergoing CABG surgery or angioplasty, cannot be identified using the registries. However, New York has a vital statistics death file that identifies all residents of the state who have died in each year, and this was linked to the two registries using patient social security numbers. Since this file is limited to New York residents, the study was also limited to this group.

The study was limited to patients who underwent CABG surgery or angioplasty after 1/1/93, because the CABG surgery registry did not contain information on detailed locations of coronary lesions (e.g., in the proximal left anterior descending artery) until 1993.

This approach led to the identification of 29,646 CABG surgery patients from the 31 hospitals in the state in which CABG surgery is performed and 29,930 angioplasty patients from the 32 hospitals in the state in which angioplasty is performed. A total of 2,552 patients from out of state or whose residence was unknown who underwent CABG surgery or angioplasty in New York during the same time period were not included in the study.

Each patient was classified into one of eight anatomic groups based on the number of vessels diseased (using ≥70% stenosis), whether there is significant disease in the left anterior descending artery (LAD) and if there is, whether it is in the proximal region.

Study end points. Patients in the study were tracked to determine if they died at any time during the study period, and if so, how long they lived after undergoing the procedure. Deaths during the same admission as the procedure were identified using the registries, and deaths after discharge following the procedure were identified using the death file. In both cases, the time between the date of the procedure and the date of death was also noted.

Similarly, all subsequent patient revascularizations (one or more CABG operations and/or angioplasties subsequent to the index procedure in the time period of interest) were captured by linking the registries using patient social security number as the primary key. All four combinations of the initial procedure and the revascularization procedure (CABG surgery/subsequent CABG surgery; initial angioplasty/subsequent CABG surgery; etc.) were examined. Note that if a patient underwent a second procedure in the hospital after the index procedure, it is reflected in these analyses as a subsequent revascularization, as well as procedures that were performed in later visits to a hospital.

Data analysis. The first analyses consisted of examining, for both the CABG surgery and the angioplasty populations, the prevalence rates for all important determinants of short- and long-term survival such as the number of vessels diseased, patient age and gender, a variety of comorbidities and measures of the patient's hemodynamic state and ventricular function.

Initial comparisons of mortality rates and subsequent revascularization rates among CABG surgery and angioplasty patients consisted of computing these rates for several time periods (in-hospital, 6 months, 1 year, 2 years, 3 years) for the different anatomic groups. It is important to note that in the analysis of "subsequent revascularization" rates, the first procedure performed defined the treatment group regardless of how many or what kind of subsequent revascularizations there were. In the mortality analyses, patients who underwent CABG surgery subsequent to angioplasty in the index admission were regarded as CABG surgery patients. The analyses were then repeated with the "intention-to-treat" principle, in which patients were permanently assigned to the initial procedure performed.

Next, 3-year survival for the two procedures was compared while controlling for differences in patient severity of illness using Cox proportional hazards models. A different model was used for each of the coronary anatomy groups defined above. The SAS procedure PHREG (Version 6.12) was used with a

Table 1. Risk Factors of Patients Undergoing CABG Surgery or Angioplasty for the First Time, in New York: 1993–1995

Risk Factor	% of CABG Surgery Patients With Risk Factor (n = 29,646)	% of Angioplasty Patients With Risk Factor (n = 29,930)	p Value
Age (yr)			< 0.001
<55	16.95	29.47	
55 to 64	26.59	28.26	
65 to 74	38.24	29.19	
75 to 84	17.31	12.06	
≥85	0.91	1.02	
Female gender	28.58	31.99	< 0.001
Ejection fraction			< 0.001
Less than 20	1.45	0.41	
Between 20 and 29	7.08	1.43	
Between 30 and 39	14.93	4.84	
Previous MI between 1 and 7 days	10.10	17.90	< 0.001
Stroke	5.27	2.13	< 0.001
Carotid/cerebrovascular disease	10.58	2.38	< 0.001
Aortoiliac disease	5.25	3.03	< 0.001
Femoral/popliteal disease	10.94	4.15	< 0.001
Hemodynamically unstable	2.80	0.83	< 0.001
Shock	0.37	0.20	< 0.001
ECG evidence of LVH	11.79	6.11	< 0.001
Persistent ventrical arrhythmia	3.02	1.51	< 0.001
COPD	15.11	4.31	< 0.001
CHF	10.48	3.60	< 0.001
Diabetes requiring medication	27.28	17.36	< 0.001
Renal failure	2.75	1.45	< 0.001

CHF = congestive heart failure; COPD = chronic obstructive pulmonary disease; ECG = electrocardiographic; LVH = left ventricular hypertrophy; MI = myocardial infarction.

stepwise approach that retains only the significant predictors of survival. Candidate independent variables in each of the stepwise analyses included all the demographic and clinical variables available in the two registries. As a second approach, all demographic and clinical variables were retained in the models for all coronary anatomy groups.

The Cox models were first used to compare relative differences between CABG surgery mortality and angioplasty mortality for each anatomic group by computing a hazard ratio, which is the ratio of the mortality of CABG surgery to the mortality of angioplasty at any given point in time, controlling for differences in the covariates (patient risk factors). First, stepwise models were developed for predicting survival using the patient risk factors. Then, the type of revascularization (CABG surgery or angioplasty, with CABG surgery coded as a 1 and angioplasty coded as a 0) was added to the models to determine if survival was dependent on the type of intervention while controlling for significant patient risk factors. The exponential of the coefficient of this variable in the Cox model is the hazard ratio for CABG surgery: angioplasty.

Also, 95% confidence intervals for the hazard ratios were calculated to test for significant differences in survival between CABG surgery and angioplasty, and then logarithms of the ratios and their confidence intervals were computed so that intervals on either side of 1.0 (0.0 for the logarithm) would have lengths that were comparable. An interval whose upper limit is below 1 (below 0 in the log scale) denotes that adjusted mortality is significantly lower for CABG surgery; an interval whose lower limit lies above 1 (above 0 in the log scale) indicates that the adjusted mortality is statistically significantly higher for CABG surgery patients (significantly lower for angioplasty patients). Note that, primarily because of operative mortality differences between CABG surgery and angioplasty, the CABG surgery: angioplasty hazard ratio is not constant over time, so that the estimate of the treatment effect is an average hazard ratio.

To measure survival differences between CABG surgery and angioplasty in percentages rather than in relative terms for each anatomic subgroup, a Cox proportional hazards model for the subgroup was used to construct adjusted Kaplan–Meier survival curves for CABG patients and for angioplasty patients. In contrast to the analyses of relative survival described above, treatment (angioplasty or CABG surgery) was used as a stratification factor instead of a modeled covariate, so that there was no need to assume that the proportional hazards assumption of the Cox models was true for the treatment variable.

For each anatomic subgroup, a survival curve for CABG surgery was calculated for each individual patient who underwent CABG surgery, and these curves were averaged across all patients undergoing CABG surgery within the subgroup to obtain a single survival curve. The process was then repeated

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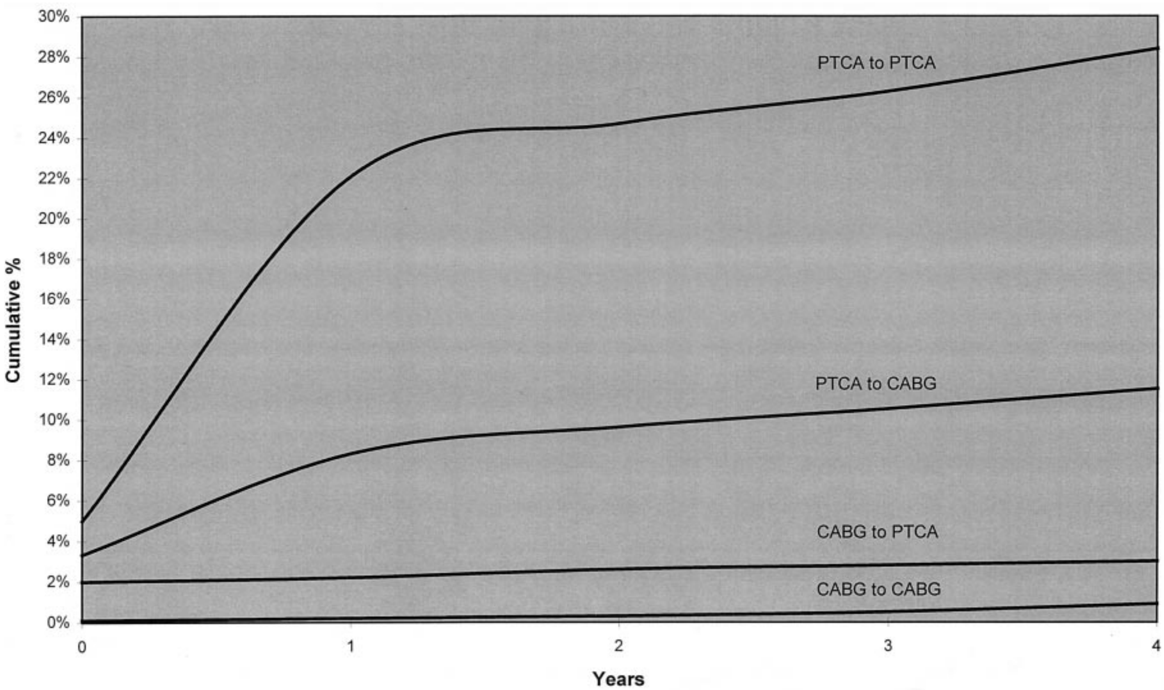


Figure 1. Percentage of patients undergoing a second revascularization procedure within 4 years. CABG = coronary artery bypass graft; PTCA = percutaneous transluminal coronary angioplasty.

for angioplasty patients in the anatomic subgroup. The resulting two curves were then plotted for each anatomic subgroup so that the absolute numerical differences in survival between CABG surgery and angioplasty, controlling for baseline differences in patient risk factors, could be viewed for each point in time. For each anatomic subgroup, the adjusted survival percentages represent an estimate of what the survival would have been if all patients in the group had undergone CABG surgery, and likewise if all patients had undergone angioplasty. Consequently, differences in preoperative risk between CABG surgery patients and angioplasty patients have been controlled for as much as possible. For each anatomic subgroup, a chi-square test was used to test for differences in 3-year survival among patients undergoing the two procedures.

In a second set of models for each of the anatomic groups, interactions between type of intervention and the significant risk factors in the initial models were added to the original risk factors to determine if there were certain types of patients for whom one of the interventions was particularly preferable. This type of analysis is especially useful when no mortality differences are found among the entire population of patients being considered, but there are significant survival differences for some subgroup (e.g., diabetic subjects).

Results

The observed (unadjusted) in-hospital mortality rate for the CABG surgery patients in the study was 1.90%, and the observed in-hospital mortality rate for angioplasty patients in the study was 0.40%. The 3-year survival rate for all CABG surgery patients in the study was 91.4%, and the 3-year survival rate for all angioplasty patients in the study was 94.6%.

Table 1 presents the demographic, clinical and angiographic characteristics of the CABG surgery and angioplasty patients in the study. Most characteristics are presented as binary variables (present, not present). For age, ejection fraction and time since previous myocardial infarction, multiple categories are used. Statistically significant differences in relative frequencies among CABG surgery and angioplasty patients are identified using chi-square tests.

As indicated, CABG surgery patients were significantly older, although there were more angioplasty patients in the 85 and older group, and were significantly more likely to be male. Also, CABG surgery patients had significantly lower ejection fractions, and had a significantly higher prevalence of all of the binary clinical measures. A significantly higher percentage of angioplasty patients had myocardial infarctions between 1 and 7 days prior to the procedure than CABG patients.

Figure 1 presents, for CABG surgery and angioplasty, the percentage of patients who underwent one or more subsequent revascularizations by type of revascularization. Of the angioplasty patients, 10.4% underwent subsequent CABG surgery and 26.6% underwent repeat angioplasties in the 3-year period. Of the CABG surgery patients, 0.5% underwent subsequent CABG surgery and 2.8% underwent subsequent angioplasties in the 3-year period.

The eight proportional hazards models developed for the purpose of risk-adjusting long-term mortality (not presented here for the sake of brevity) yielded between five and 12 significant preprocedural risk factors. Risk factors that proved

Table 2. Three-Year Survival by Treatment in Each Anatomic Subgroup

Coronary Anatomy Group	Patients	Observed Survival (%)	Adjusted Survival (%)	p Value	95% Confidence Interval for Adjusted Survival Differences (CABG Surgery − PTCA)
One vessel, No LAD					
CABG	507	89.2	92.4	0.003	(−0.006, −0.052)
PTCA	11,233	95.4	95.3		
One vessel, nonproximal LAD					
CABG	153	95.8	96.0	0.857	(−0.029, 0.035)
PTCA	4,130	95.7	95.7		
One vessel, proximal LAD					
CABG	1,917	95.8	96.6	0.010	(0.004, 0.024)
PTCA	5,868	95.5	95.2		
Two vessel, no LAD					
CABG	1,120	91.0	93.0	0.664	(−0.014, 0.022)
PTCA	2,729	93.4	92.6		
Two vessel, nonproximal LAD					
CABG	850	91.3	92.3	0.438	(−0.029, 0.013)
PTCA	2,300	93.3	93.1		
Two vessel, proximal LAD					
CABG	7,242	93.5	93.8	< 0.001	(0.009, 0.033)
PTCA	2,376	92.8	91.7		
Three vessel, nonproximal LAD					
CABG	1,984	90.1	90.3	0.002	(0.013, 0.073)
PTCA	660	86.7	86.0		
Three vessel, proximal LAD					
CABG	15,873	90.1	90.3	< 0.001	(0.015, 0.069)
PTCA	634	88.2	86.1		

CABG = coronary artery bypass graft; LAD = left anterior descending artery; PTCA = percutaneous transluminal coronary angioplasty.

to be significant in five or more of the models were age and renal failure (all eight models), chronic obstructive pulmonary disease, congestive heart failure (CHF) and diabetes (seven models), ejection fraction (six models) and femoral/popliteal disease (five models).

Table 2 presents, for each of the eight anatomic groups, the number of patients undergoing CABG surgery and angioplasty between 1993 and 1995, the observed 3-year survival and the adjusted 3-year survival (based on the proportional hazards model for that anatomic group). Also, p values are provided for tests of the differences in 3-year adjusted survival between CABG surgery and angioplasty. The table demonstrates that there are statistically significant 3-year survival differences for five of the anatomic groups. For patients with one-vessel disease/no LAD, angioplasties had a statistically significantly higher 3-year adjusted survival than CABG surgery (95.3% vs. 92.4%). For patients with one-vessel disease/proximal LAD and with two-vessel disease/proximal LAD, CABG surgery had a statistically significantly higher adjusted survival (96.6% vs. 95.2%, and 93.8% vs. 91.7%, respectively). Also, both groups of patients with three-vessel disease (nonproximal LAD and proximal LAD) exhibited a statistically significantly higher survival with CABG surgery (90.3 vs. 86.0 and 90.3 vs. 86.1, respectively). Note that the relatively low survival rate for one-vessel disease/no LAD patients undergoing CABG surgery was not related to the 22% of these patients for whom angioplasties had failed. Their survival rate (94.3%) was actually higher than the CABG patients in this anatomic group without failed angioplasties (87.8%).

Figure 2 presents the logarithms of the adjusted hazard ratios for CABG surgery: angioplasty for each of the eight anatomic groups. This characterization differs from Table 2 in that Table 2 presents survival differences after 3 years, whereas the hazard ratios in Figure 2 represent the logarithms of the average relative advantage of one intervention compared to the other over the course of the 3-year period. Statistically significant relative differences in Figure 2 are represented by confidence intervals that do not overlap the vertical line at 0.0. The results in Figure 2 are consistent with the results in Table 2 in that there were statistically significant survival differences by treatment choice for the same five anatomic groups. Again, angioplasty had a statistically significantly higher relative survival for one-vessel disease/no LAD, with an adjusted hazard ratio of 1.643 (obtained by exponentiating the log scale value presented in Fig. 2). Coronary artery bypass graft surgery had a statistically significantly higher relative survival for one-vessel disease/proximal LAD, two-vessel disease/proximal LAD and both three-vessel disease groups (with relative hazard ratios of 0.700, 0.695, 0.670 and 0.586, respectively). Identical results were obtained with respect to significance when the statistical models were redone using all risk factors rather than retaining only the significant risk factors in a stepwise analysis.

Figures 3 to 7 present the 3-year adjusted survival curves for CABG surgery and angioplasty for all five of the eight ana-

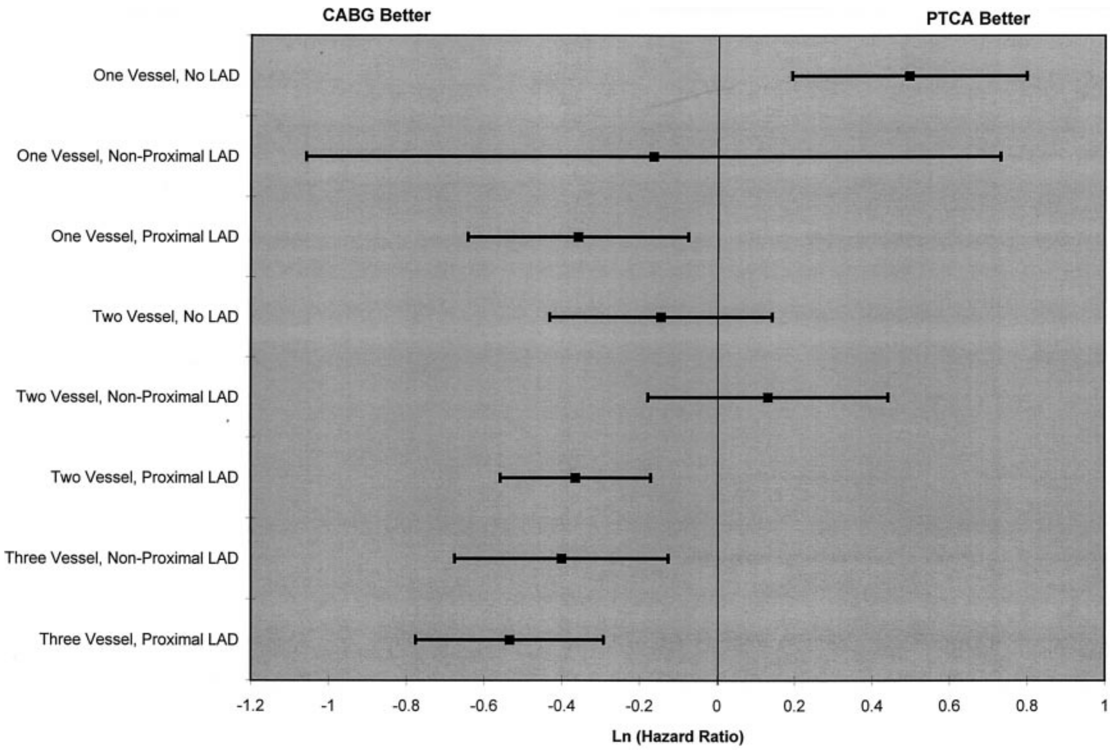


Figure 2. The 95% confidence interval for Ln (adjusted hazard ratio) of CABG patient death: PTCA patient death within a 3-year period (excluding patients with myocardial infarction less than 24 h before procedure). LAD = left anterior descending artery.

tomic groups with statistically significant survival differences. Note that the 3-year end points match with the 3-year adjusted survival rates given in Table 2, and that the curves differ only in that they also provide intermediate adjusted survival rates. Of particular interest is that one of the curves (Fig. 6) exhibits a crossover, whereby survival is initially higher for angioplasty (as a result of the higher procedural mortality rate for CABG surgery), but that eventually survival becomes higher for CABG surgery. This anatomic group is three-vessel disease/nonproximal LAD, for which CABG surgery exhibited a statistically significantly longer survival on average and at the end of 3 years. However, angioplasty does have a higher survival up until about 6 months after the procedure is performed.

The next step in the analysis plan consisted of investigating, for each anatomic group, interactions between treatment type (angioplasty, CABG surgery) and the significant clinical variables in the proportional hazards model for that group. The only group for which there was a significant interaction was two-vessel disease/proximal LAD, for which there was a significant interaction between treatment type and CHF. The direction of the interaction was such that the differential in survival between CABG surgery and angioplasty patients was increased even more among patients with CHF.

When the data in Table 2 and Figures 2 to 7 were recomputed based on the "intention-to-treat" principle, in which patients were permanently assigned to the first treatment they underwent, the results were essentially the same, with the same groups exhibiting significant differences.

Discussion

Summary of results and contrast with other studies. This study has reported on long-term survival differences between CABG surgery and angioplasty in New York State. Four other recent studies on this topic were multi-institutional randomized trials (3–6), and as reported in the study by Jones et al. (7), a meta-analysis that combined the results of the first three of these clinical trials concludes that there is no difference in total mortality between CABG surgery and angioplasty for 2,794 patients with two- or three-vessel disease. It is very important to emphasize that none of the randomized clinical trials distinguished those patients with proximal LAD disease from patients without proximal LAD disease. In other words, patients were grouped for analysis only on the basis of number of vessels diseased, not on the location of the disease.

The aforementioned study by Jones et al., which was based on the Duke University Registry, and was not a randomized trial, found no long-term mortality differences between CABG surgery and angioplasty among all 3,648 two- and three-vessel disease patients (7). However, when these patients were placed into subcategories based on degree of stenosis (≥75%, ≥95%) and the presence of significant lesion in the proximal LAD, differences in the effectiveness of CABG surgery and angioplasty were detected. Specifically, all patients with three-vessel

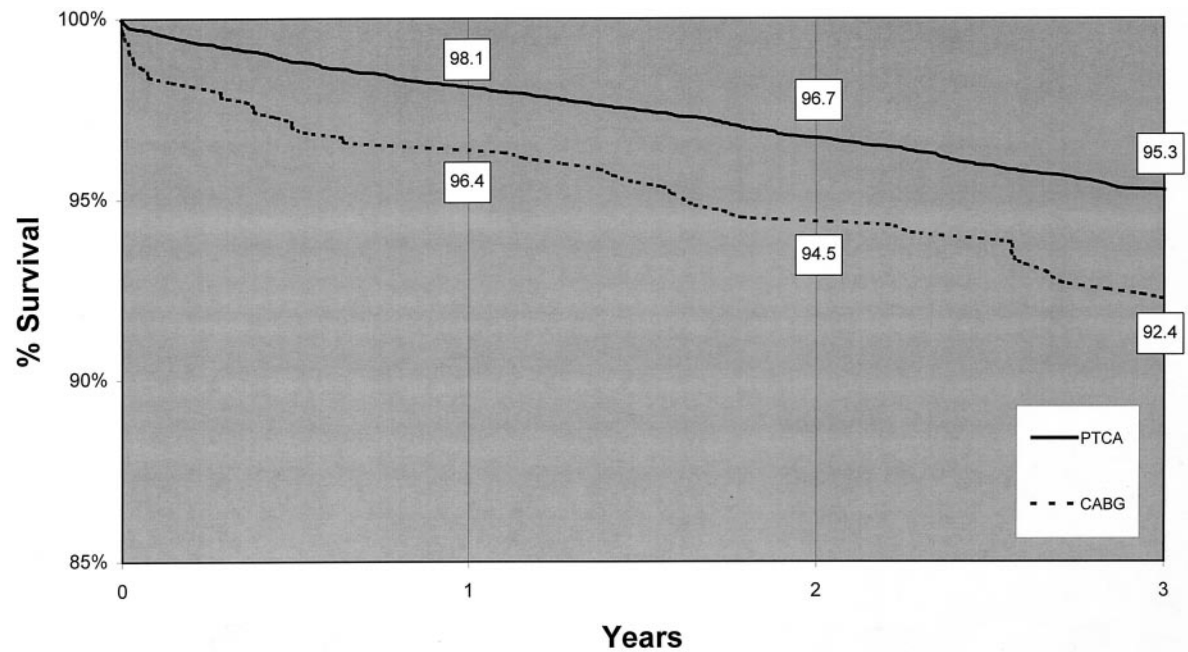


Figure 3. Adjusted Kaplan–Meier survival curve: CABG versus PTCA for one-vessel disease/no LAD. Abbreviations as in Figure 2.

disease and those patients with two-vessel disease/proximal LAD had statistically significantly longer survival times with CABG surgery. Patients with one-vessel disease/no LAD had statistically significantly longer survival times with angioplasty. Other patients did not have significantly different survival times for the two procedures.

The results of this study are virtually the same as those in the Jones et al. study. Again, patients with one-vessel disease/no LAD had statistically significantly longer survival times with angioplasty. Also, all patients with three-vessel disease and patients with two-vessel disease/proximal LAD had statistically significantly longer survival times with CABG surgery. The one difference was that patients with one-vessel disease/proximal LAD had statistically significantly longer survival times with CABG surgery in this study. In the Jones et al. study, these patients (defined as one-vessel disease/≥95% proximal LAD) were combined with two-vessel disease/no

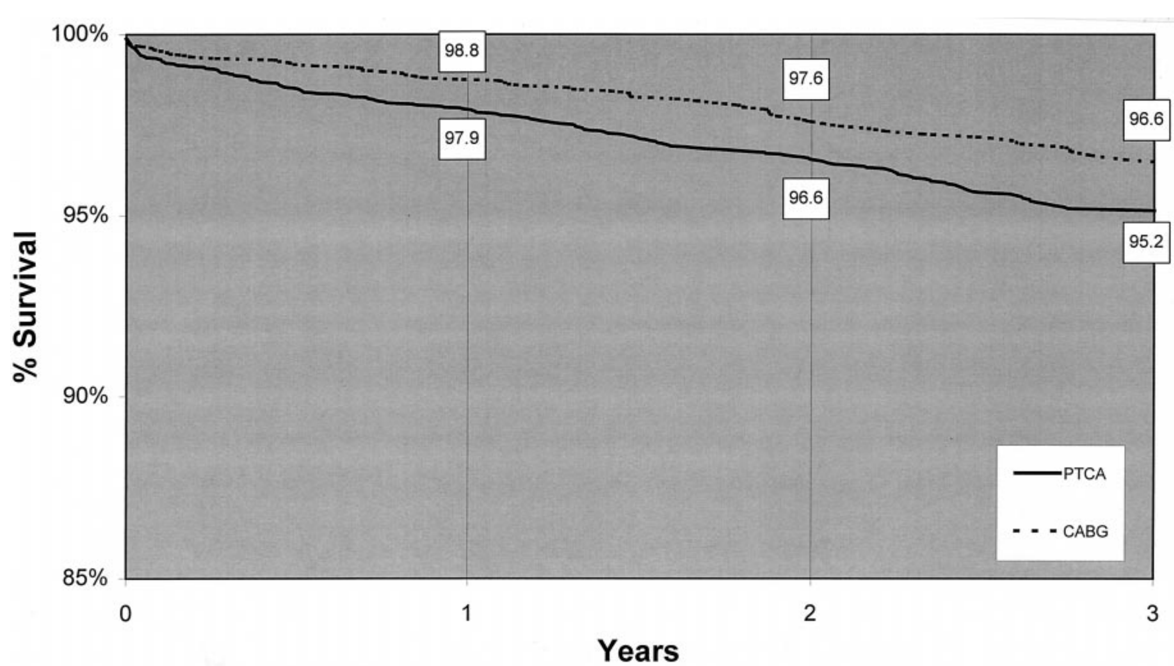


Figure 4. Adjusted Kaplan–Meier survival curve: CABG versus PTCA for one-vessel disease/proximal LAD. Abbreviations as in Figure 2.

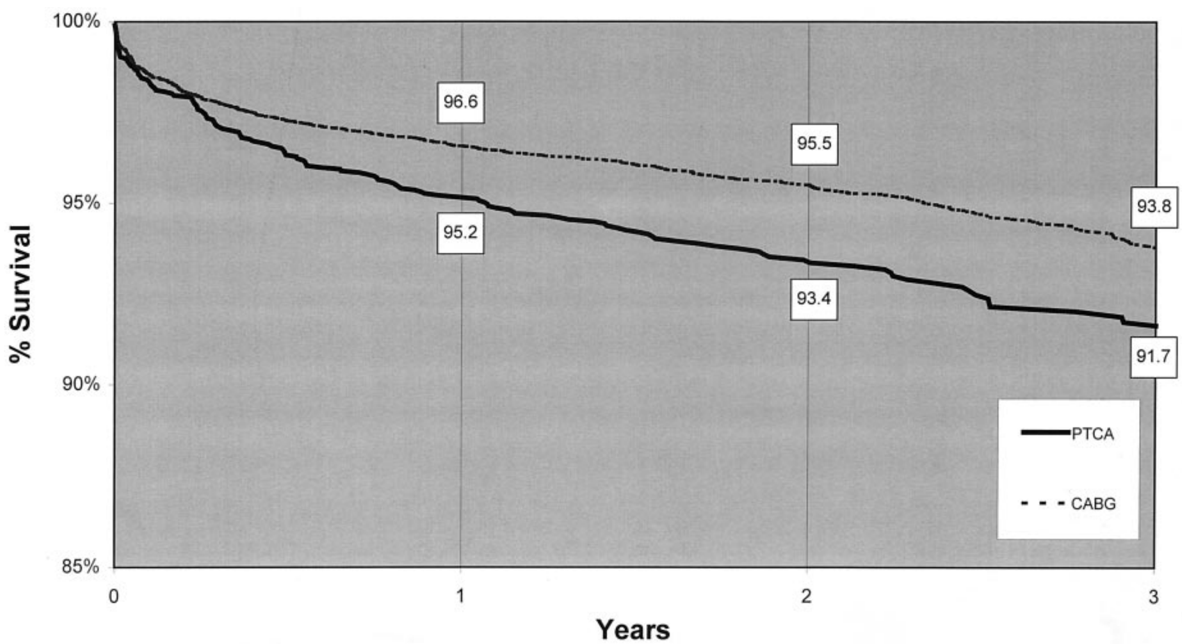


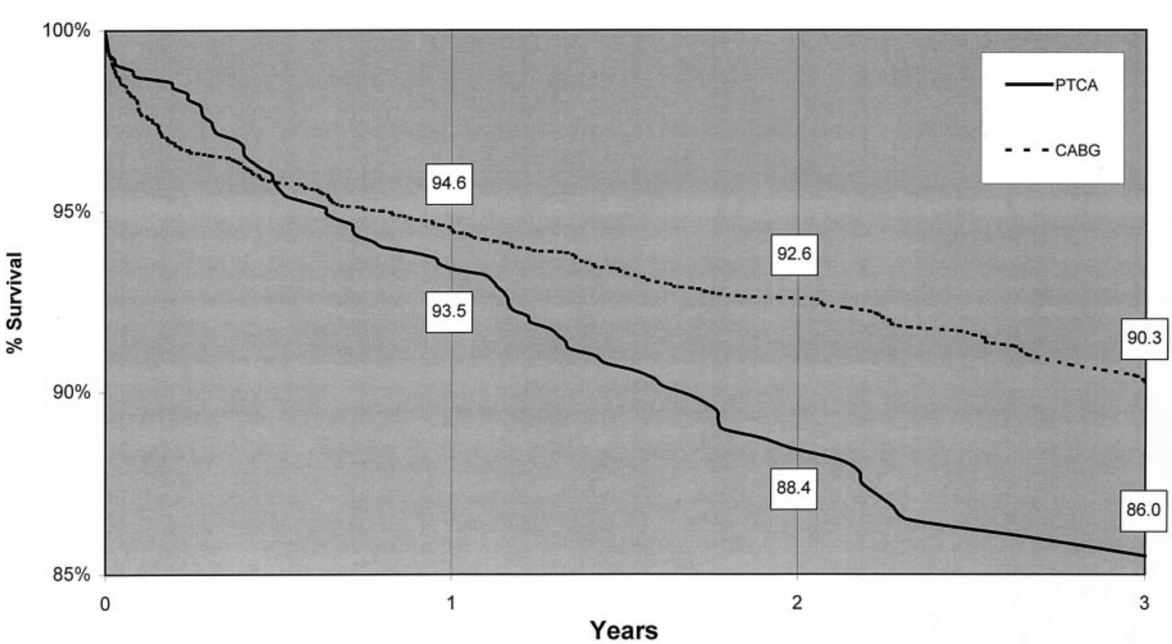
Figure 5. Adjusted Kaplan–Meier survival curve: CABG versus PTCA for two-vessel disease/proximal LAD. Abbreviations as in Figure 2.

LAD patients, and were found to have longer but not significantly longer survival with CABG surgery. When we combined the two groups and used a 99% confidence interval as Jones et al. did, we also found that the new group had higher, but not significantly higher, survival with CABG surgery.

Figure 6. Adjusted Kaplan–Meier survival curve: CABG versus PTCA for three-vessel disease/nonproximal LAD. Abbreviations as in Figure 2.

With regard to diabetic patients, the fourth of the clinical trials mentioned above, the BARI study, found that 5-year cardiac mortality for CABG surgery was significantly lower than that for angioplasty, but that there was no statistically significant difference when the analyses were restricted to nondiabetic patients. However, there were only 1,476 nondiabetic patients in the study prior to randomization (6). Also, a study by Gum et al. that concentrated on diabetic subjects found that diabetic patients undergoing CABG surgery had lower 6-year mortality and cardiac event rates than diabetic patients undergoing angioplasty (12).

In contrast to these findings, we found that there were



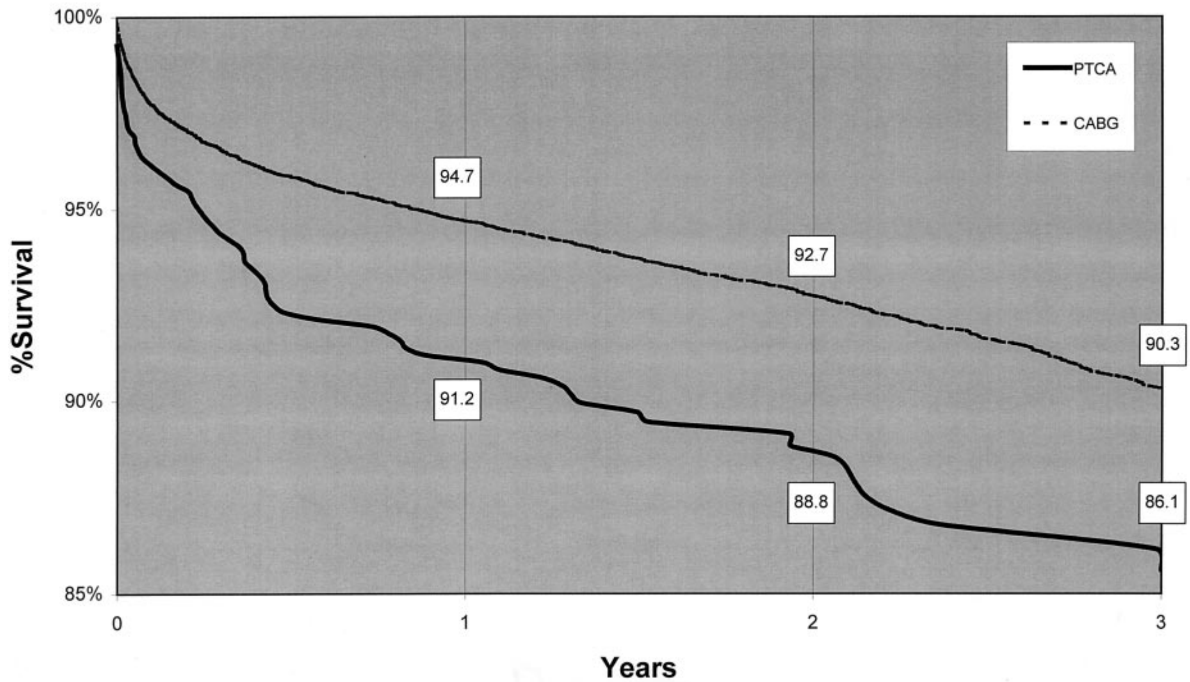


Figure 7. Adjusted Kaplan–Meier survival curve: CABG versus PTCA for three-vessel disease/proximal LAD. Abbreviations as in Figure 2.

statistically significant differences in mortality between patients undergoing CABG surgery and angioplasty among five of the eight anatomic groups we studied (with higher survival among CABG surgery patients for four of the five groups) for all patients in the study, and that these differences remained when we restricted the study to nondiabetic subjects. This finding was further confirmed by the finding that there was no significant interaction in the proportional hazards models between treatment type and diabetes.

Caveats. There are several important caveats. First, the study is not a randomized clinical trial. Consequently, choice of treatment was influenced by clinicians' opinions of the "right" option. We have attempted to minimize the selection bias introduced by this "reality of practice" by adjusting for differences among patients in demographics, comorbidities, ventricular function and hemodynamic state. Nevertheless, unmeasured differences in patient severity of illness could account for differences in long-term outcomes between the two competing interventions. However, the results of this study and of another nonrandomized study by Jones et al. (7) are sufficiently close to results emanating from clinical trials to support using observational database analyses to study the relative effectiveness of alternative interventions. In fact, given the much larger sample sizes and much lower costs associated with using observational databases, registries such as the one in New York State may serve as an important supplement to randomized clinical trials.

Another important caveat is that, like all studies of this nature, comparative studies of CABG surgery and angioplasty can become rapidly outdated in view of evolving improvements in procedural technology and technique. For example, there have been refinements in cardiac anesthesia and operative techniques for CABG surgery, such as the type of cardioplegia used, the increased use of arterial grafts and the use of minimally invasive surgery. The increased use of intracoronary stents for angioplasty patients appears to decrease the restenosis rate. Although long-term survival data are not yet available, it is fair to say that advances in angioplasty in the past 3 to 5 years have been much more dramatic than advances in CABG surgery. It is therefore possible that future studies will result in very different conclusions once long-term survival data for stent patients become available. Note that for the study period, a total of 3,537 angioplasty patients (11.8%) received stents, and that the percentage ranged from 10.45% of patients with three-vessel disease, nonproximal LAD to 15.24% with two-vessel disease, proximal LAD.

It should also be emphasized that we have reported statistically significant differences, but that these differences may not be of clinical significance. There are many important considerations in the choice of procedure, including the patient's life expectancy and the attitude of the patient toward taking risks. For example, when the long-term survival curves cross, this means that one of the procedures is preferable for some period of short-term survival, and the other is preferable when longer term survival is used as the criterion. In this study, survival curves crossed for three-vessel disease/nonproximal LAD (for which CABG surgery had a statistically significantly longer adjusted survival, but angioplasty had a higher probability of short-term survival). Crossovers may occur because of the higher operative mortality for CABG surgery (leading to lower short-term survival for CABG surgery) and more complete revascularization in CABG patients (leading to higher long-term survival for CABG patients). A risk-averse patient may prefer the treatment that has superior short-term survival (angioplasty in this case) even though the long-term survival is lower. Consequently, it is preferable to present detailed information about the nature of the adjusted survival curves to patients when the curves cross. An excellent comprehensive discussion of these issues is presented by Howard et al. (13).

One difference between our study and the ones referenced above is that we did not include patients who had suffered an acute myocardial infarction in the 24-h period prior to the surgery. This group was eliminated from consideration because it was felt that a higher percentage of salvage patients (whose true preprocedural risk could not be accurately estimated) underwent angioplasty. We repeated the study with this group included and found that all the significant differences in 3-year mortality reported in the Results section remained, although in general the survival for CABG surgery improved in relation to angioplasty survival, presumably because of the salvage group mentioned above.

Another limitation is that because resources were not available to follow patients after discharge, we were only able to capture deaths for New York State residents (using the New York State death file) and revascularizations that occurred in New York hospitals (by linking data from the two registries [i.e., CABG surgery and angioplasty] that were used to obtain other data in the study). We attempted to minimize the bias introduced by this limitation by restricting ourselves to patients residing in New York during the performance of the index procedure, but we were not able to capture deaths of patients who moved to another state or subsequent revascularizations of patients that were performed in another state.

However, we had access to Medicare data (limited to patients 65 years old and older) from a different time period (1991–1992) that were compared to Registry data from the same time period to estimate the deaths missed because of patients moving out of state. The difference in 3-year survival between the two databases was only 0.8% (87.6% for Medicare vs. 88.4% for the Registry), and there was no bias in deaths lost by type of intervention. Consequently, we do not feel that the findings reported here are substantially different than they would have been if out-of-state deaths could have been captured.

It should also be noted that not all vessels may have been completely revascularized. Previous studies have shown that long-term outcomes may be related to the completeness of revascularization, which in certain instances may be more achievable with CABG surgery because of the increased technical ability to revascularize total occlusions, particularly in patients with three-vessel disease. However, the completeness of revascularization in both CABG surgery and angioplasty is an operator choice that involves balancing the safety of the procedure with its long-term effectiveness, and this study presents the results of those decisions.

Another caveat is that the primary end point used in this study was all-cause mortality. Cardiac deaths were impossible to obtain because autopsy data were not available, and the "cause of death" field in the death file is not believed to be sufficiently accurate for identifying cardiovascular deaths. Also, we were unable to obtain information on restenosis that did not result in revascularization and we did not identify whether revascularization was performed on repeat target vessels or on new vessels. Furthermore, subsequent revascularization was analyzed without adjusting for patients' preprocedural risk. All three of these topics are worthy of future studies, although restenosis without revascularization cannot be investigated with the current New York database. Future studies will address the other topics as well as update this study to reflect the impact of procedural improvements.

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